2.2 Astronomy

Figure C2.20

For thousands of years, humans have been living north of the Arctic Circle. To thrive in this beautiful but sometimes harsh environment, the First Peoples need a detailed knowledge of the interconnections among a number of complex systems: ecosystems, weather patterns, seasonal variations in climate, and other interactions between the terrestrial and marine environments. For example, successful hunting depends upon a knowledge of the seasonal variations in sea ice and how these changes affect the behavioural patterns of marine mammals, like whales, seals, and walruses.

As you learned in Units A and B, the traditional ecological knowledge of the Inuit has been acquired over thousands of years through their direct contact with the environment. This is a dynamic approach to developing new understandings of human interactions with the environment. This view of the world focuses on the inseparable relationships among land, resources, and culture. Since the environment includes the effects of objects that are beyond Earth, human interaction with this part of the environment also plays a role in traditional ecological knowledge.

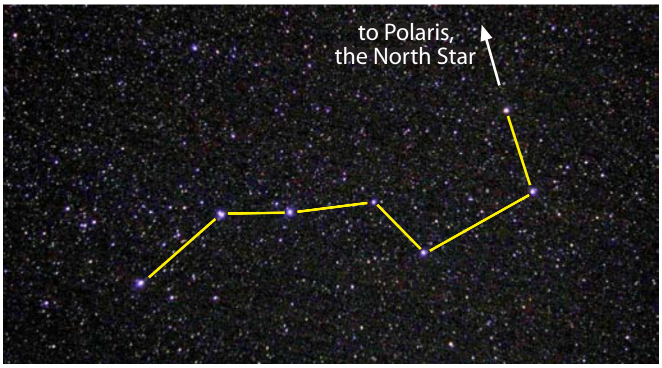


Figure C2.21: The Big Dipper constellation

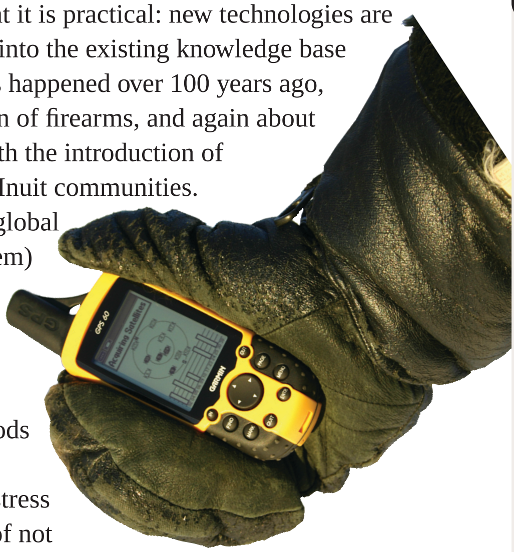
The group of stars in Figure C2.21 is perhaps the most familiar to people living in the northern hemisphere. Some cultures call this **constellation** the Big Dipper. Others recognize it as a small part of a larger constellation called the Great Bear. For the Inuit living in the Arctic, this constellation represents a caribou. This constellation is important because it can be used to locate the North Star—a valuable reference point when navigating at night, especially on moving sea ice.

constellation: a group of stars perceived as being in the shape of a figure or a design

Given that the arctic environment consists of vast tracts of nearly featureless territory and that the Sun is continually below the horizon for many weeks of the arctic winter, survival depends upon an efficient and reliable system of being able to find your way. Traditional navigation techniques involve using a number of different indicators from the environment, including stars, wind patterns shown by the subtle shapes of snowdrifts, and rock cairns called inuksuk.

Figure C2.22: Inuit Elders explain that inuksuks are stone monuments that guide the people on the land and serve to mark special places, many of them sacred.

An important aspect of Inuit traditional ecological knowledge is that it is practical: new technologies are often integrated into the existing knowledge base and culture. This happened over 100 years ago, with the adoption of firearms, and again about 40 years ago, with the introduction of snowmobiles to Inuit communities. Recently, GPS (global positioning system) technology has been adapted as a new tool to supplement the traditional methods of navigation.



Inuit Elders stress the importance of not relying too heavily on this new technology. The extreme cold of the arctic environment can cause the batteries that power the GPS receivers to fail and can leave the display screens inoperable. Becoming lost on the tundra or on the frozen surface of the Arctic Ocean can truly be a matter of life and death! That's why the Elders recommend the hunters continue to practise the traditional navigation techniques, with GPS technology only being used to assist in certain circumstances. Being able to navigate by the stars is still an important survival skill for the Inuit who obtain traditional sources of food through hunting.

In addition to navigation, for thousands of years the relative positions of the stars in the night sky have provided the Inuit with a reliable way to mark the passing of time. Given the scarcity of light during the arctic winter, it is important to be able to predict the hours of daylight available for any given day so that activities can be planned. The position of the Big Dipper relative to the North Star is used as a clock to determine time. The positions of other constellations on the horizon are used, along with other environmental clues, as a calendar to track the passing of the seasons and the periodic changes in animal migration patterns.

Using EMR from Beyond Earth

Electromagnetic radiation from objects in outer space has played an essential role in human existence for a long time. Today, people are still gathering information from stars in an effort to better understand the universe and to improve daily life. In this lesson you will see how the characteristics of the electromagnetic spectrum have been applied to these studies and to the science of **astronomy**.

astronomy: the science of objects and phenomena that originate outside Earth's atmosphere

Practice

26. Consider the idea of utilizing electromagnetic radiation from beyond Earth.

- **a.** How does Figure C2.20 on page 436 relate to this idea?
- **b.** Describe some of the ways you use electromagnetic radiation from beyond Earth.

27. A technology used to solve one problem can often be the source of a new set of unintended problems.

- **a.** Explain how the introduction of CFCs as a refrigerant illustrates this idea.
- **b.** Explain how this idea could apply if the next generation of Inuit hunters did not learn the traditional navigation techniques and came to rely exclusively on GPS technology.
- **c.** Interconnectedness is a key characteristic of traditional ecological knowledge. Explain how this characteristic is helpful for reducing some of the negative impacts associated with the introduction of new technologies.

The Nearest Star

Which star is closest to Earth? Would you have to use an Internet search engine to answer this question, or would you think "outside the box" and come up with the answer of the Sun.

The heat and light that is so essential to life on Earth is the result of nuclear reactions deep within the Sun's interior. Within the Sun's core, the temperature is estimated to be about 15 000 000°C, and the pressure is thought to be millions of times higher than the atmospheric pressure on Earth. Under these circumstances, molecules are torn apart into atoms, and electrons are stripped from atoms, leaving the positively charged nuclei. A series of collisions between hydrogen nuclei results in the formation of a helium nucleus and the release of gamma photons. This reaction is called **nuclear fusion**.

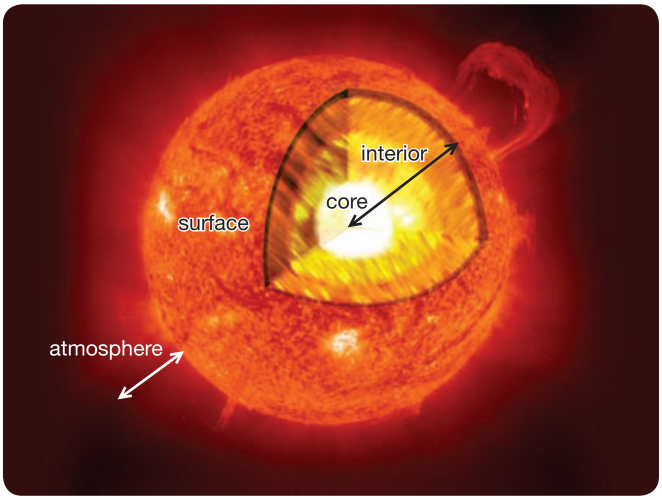


Figure C2.23

nuclear fusion: a process in which two smaller nuclei join to form a larger nucleus, releasing energy

Science Links

Just as chemical reactions are described with chemical equations, nuclear reactions are described with nuclear equations. You'll learn more about nuclear reactions and the equations used to describe them in Unit D.

$$\boxed{{}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n}$$

EMR Emitted by the Sun

As a gamma photon is released from a fusion reaction and travels outward from the Sun's core, a countless number of interactions occur between the photon and the charged particles that make up the Sun's interior. In each interaction, the energy of the photon is absorbed and then re-emitted. However, since the charged particles are given kinetic energy in these interactions, the re-emitted photon emerges with less energy than the incoming photon. After an innumerable number of collisions, the photons that eventually reach the Sun's surface no longer have the energy of gamma photons.

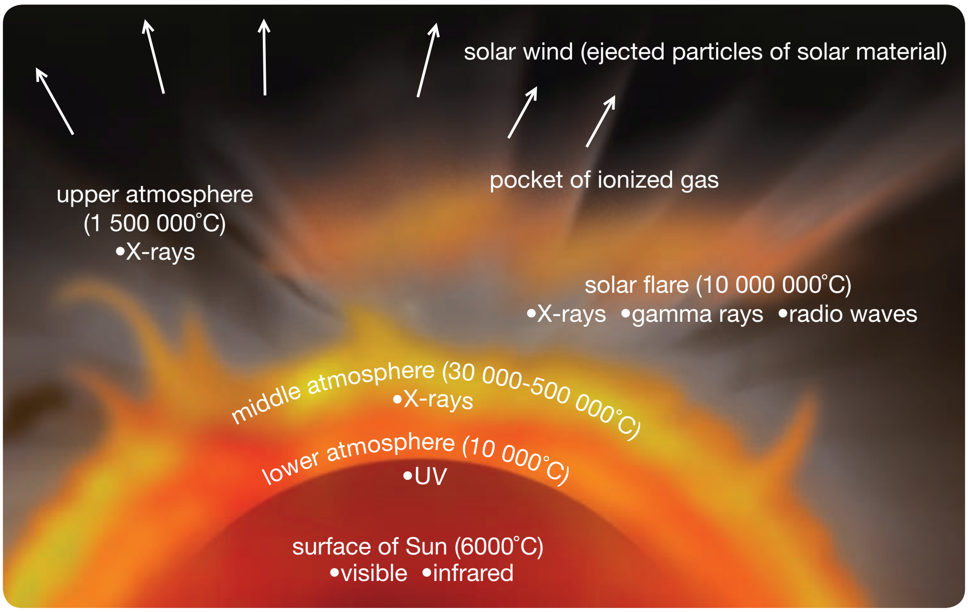
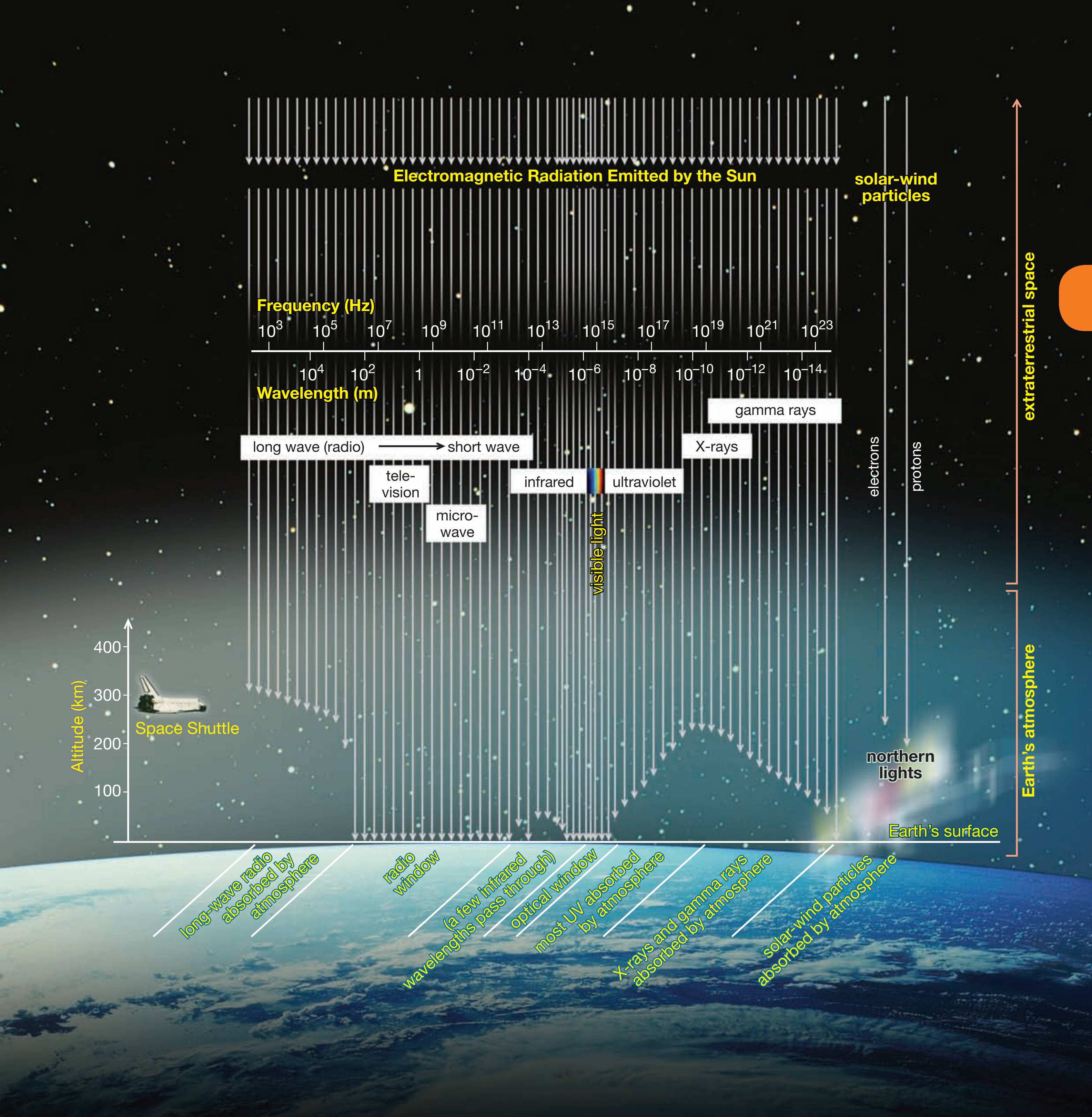


Figure C2.24

The electromagnetic radiation from the Sun's surface consists of visible and infrared photons. This is consistent with the behaviour of objects that have the same temperature as the surface of the Sun, about 6000°C. For reasons that are not entirely understood, the temperature of the Sun's atmosphere increases with height above the surface of the Sun. As shown in Figure C2.24, as the temperature in a region of the Sun's atmosphere increases, the energy of the emitted radiation also increases. This is why the photons with the most energy, X-rays and gamma rays, are emitted from the hottest region of the Sun's atmosphere in a solar flare. A solar flare is a very powerful eruption in the Sun's atmosphere that is triggered by the sudden realignment of intense magnetic field lines emerging from the surface of the Sun. Even though radio waves have the lowest energy content of all EMR, they are produced by solar flares as well. The fluctuations of these huge regions of intense magnetic field lines accelerate charged particles in the vicinity, causing these particles to emit radio waves.



The Sun emits radiation across the whole electromagnetic spectrum—from radio waves to gamma rays; however, only a fraction of this radiation is able to reach the surface of Earth. The atmosphere provides a window for only short-wavelength radio waves and the wavelengths of EMR close to the visible spectrum (short-wavelength infrared, visible light, UVA, and UVB).

As you learned earlier in the course, molecules of oxygen and ozone absorb the energy of the more energetic UVC photons. These are not the only molecules in the atmosphere that can absorb EMR. Recall from previous courses that molecules of water vapour, methane, and carbon dioxide are able to absorb infrared radiation. This causes the kinetic energy of these molecules to increase, adding to a general heating of the atmosphere that is often called the "greenhouse effect."

The X-rays and gamma rays from the Sun tend to be absorbed by collisions with individual atoms. These collisions ionize the atoms and liberate electrons. The electrons then act to absorb the energy of the long-wavelength radio waves.

Practice

28. Trace the path of energy that is released at the Sun's core to the type of EMR that is released from the surface of the Sun.

29. Refer to Figure C2.24, which shows the details of the Sun's surface and atmosphere.

- **a.** Identify a region of the Sun that emits UV photons.
- **b.** Identify a region of the Sun that emits X-ray photons.
- **c.** Explain the characteristic of each region of the Sun that determines the type of EMR emitted.

30. Astronomers and other scientists use detectors and other scientific instruments for studying the EMR emitted by the Sun.

- **a.** Explain why there are limits to the EMR that can be studied if the detectors are placed on the surface of Earth.
- **b.** Suggest alternative locations for some of the EMR detectors that would expand the EMR that can be studied.

Exploring the Properties of Visible Light

Figure C2.25: Sunlight is bent as it travels through ice crystals, creating the illusion that the Sun has two bright companions, called "sundogs."

Although daytime during the arctic winter is short, it would be a mistake to assume that winter days in the north are dreary. Since the Sun stays close to the horizon in the winter, the conditions are ideal for an interesting atmospheric phenomenon called sundogs. In Figure C2.25, a pair of bright patches of light can be observed on each side of the Sun. Because these patches of light "sit obediently" on each side of the Sun and often appear to have "tails of light" that stream away from the Sun, they are called sundogs. Sundogs are caused by the **refraction**, or bending, of light from the Sun as the rays travel through ice crystals in the atmosphere. Sundogs are a common occurrence in Alberta as well, also because the Sun spends a great deal of time near the horizon during the winter months.

- **refraction:** a bending in the direction of a wave that occurs when the wave changes speed
- **reflection:** a return of a wave from a boundary
- **polarization:** confining a wave to vibrate in one direction
- **diffraction:** the bending of a wave as it passes by obstacles or by the edges of an opening

The low position of the Sun in the sky, combined with the abundance of snow, accounts for the tremendous amount of **reflection** that can occur on a winter's day. People who enjoy outdoor winter activities can protect their eyes from the glare by wearing sunglasses. The most effective type of sunglasses deal with the annoying glare by taking advantage of the fact that **polarization** occurs as light reflects from horizontal surfaces. Manufacturers refer to this feature on sunglasses by advertising that the lenses are polarized.

Figure C2.26: Polarized lenses in sunglasses help to absorb the light energy reflected from horizontal surfaces.

In the next investigation you will have an opportunity to learn more about reflection, refraction, and polarization—as well as another property of light called **diffraction**. The diffraction that occurs as light rays pass through the pupil of the eye helps explain why people have a difficult time distinguishing the visual details of objects that are far away.

Investigation

Observing the Properties of Visible Light

Science Skills
✓ Initiating and Planning
✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will use data tables and labelled diagrams to gather data and record observations related to the reflection, refraction, diffraction, and polarization of visible light.

CAUTION!

In parts of this investigation, you have the option of using a ray box or a laser pointer to produce rays of light. If you are using a laser pointer, it is important to employ all the recommended safety precautions to avoid having light from this source travel directly to your eyes.

Mandatory Safety Precautions for Working with Laser Light

- Never aim a laser at a person's eye.
- Avoid having the unprotected eye along or near the beam axis.
  - If you are working at a table, this means keeping the laser light parallel to the table's surface so that your eyes are well above the work surface.
  - Anticipate the path the laser light will take and arrange the apparatus so that the beam will not inadvertently be directed near the eyes of other students. One useful strategy is to work around the perimeter of the room, with the laser light directed toward the outside wall. This arrangement also ensures that your eyes are facing away from other groups.
- Keep the room well-lit so pupils remain small, reducing the "window" available for the entry of laser light.
- Avoid having the laser produce light for extended periods of time. Once the apparatus is in place, most measurements or observations can be made in a matter of seconds, and then the laser can be switched off.

Materials

The materials for each part of this investigation are listed on the handouts.

Procedure, Observations, and Analysis

step 1: Obtain each of the following handouts from the Science 30 Textbook CD:

- "Investigating Refraction"
- "Investigating Polarization"
- "Investigating Diffraction"
- "Investigating Reflection"

step 2: For each handout, complete the procedure, collect the data, and record your observations according to the instructions provided.

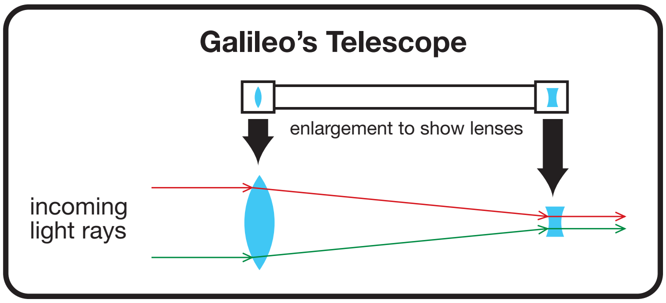
Astronomers Apply the Properties of Visible Light

With the exception of some moon rocks retrieved during the Apollo missions, astronomers are not able to physically touch the objects they are studying. Distant planets, stars, comets, and clouds of interstellar dust are too far away to retrieve samples. Fortunately, the electromagnetic radiation that is emitted or reflected from objects in space provides a rich source of information. Thousands of years ago, the first astronomers used their eyes to observe the visible light emitted by objects in the heavens. Astronomers' ability to observe the heavens was significantly improved with the invention of the telescope about 400 years ago.

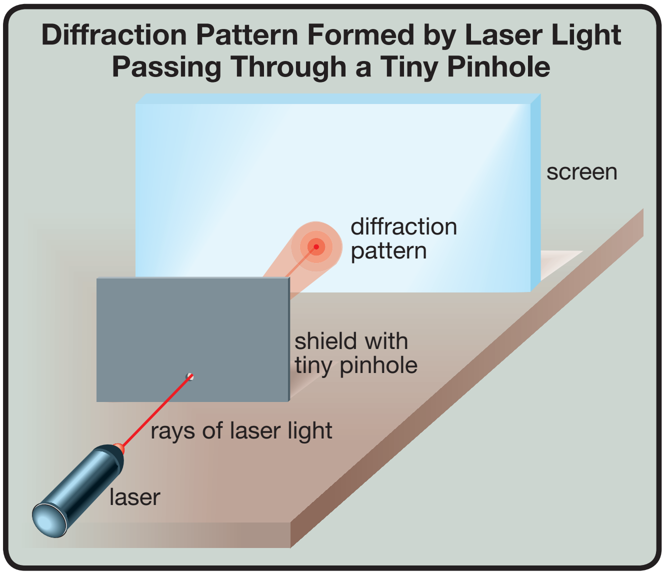
Galileo's Refracting Telescope

Even though these devices were simple by today's standards, Galileo was able to observe the craters of the Moon, the four moons of Jupiter, and the rings of Saturn. The simple telescope he used consisted of a convex lens at one end and a concave lens at the other.

It is remarkable that Galileo was able to make such detailed observations with such a primitive instrument. One problem was the quality of the glass used to make the lenses. Other problems were related to the fact that his design forced the light to enter the telescope through a relatively small opening. The small opening produced two problems. The first problem was that very little light was able to enter the instrument. This meant that faint sources would have looked quite dim to Galileo and would have been difficult to see. The second problem was that sources that were close together would have been difficult to distinguish due to the effects of diffraction.

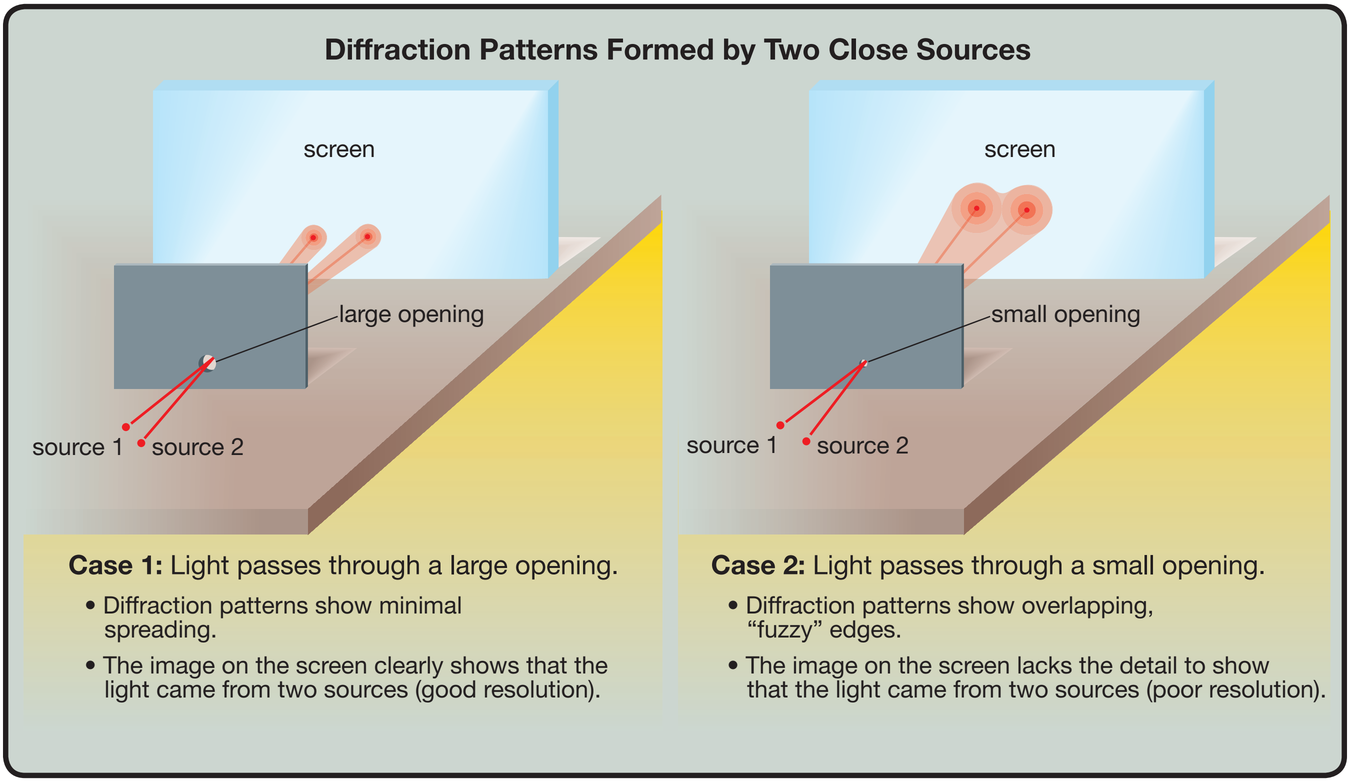


Diffraction occurs when light passes through a tiny opening. This can be demonstrated if laser light passes through a tiny opening and then travels to a distant screen. Instead of the laser light forming an exact image of the tiny hole, it spreads out, producing a pattern of concentric circles called a **diffraction pattern**.



Two sources that are close together will each produce a diffraction pattern when the light from these sources passes through narrow openings. If the opening is large enough, the objects may look a little fuzzy, but on the screen two distinct images are formed. If the opening is too small, the amount of diffraction can increase to the point where the diffraction patterns overlap, making it difficult to determine if there are two sources or just one.

diffraction pattern: a pattern produced by waves that have undergone diffraction



Astronomers describe the ability of a telescope to distinguish the fine details of an object or collection of objects as the **resolution** of the telescope. Diffraction means that telescopes capable of resolving the details of finely spaced objects must have large openings to reduce the effects of overlapping diffraction patterns. Although it was understood at the time that a telescope with a wider opening would be desirable, the properties of glass imposed limits on the size of the lenses that could be used. The force of gravity acting on a large mass of glass made mounting the glass very difficult, and eventually pulled the glass out of shape—reducing the effectiveness of the lens to form a crisp image. Larger telescopes would require a new technology.

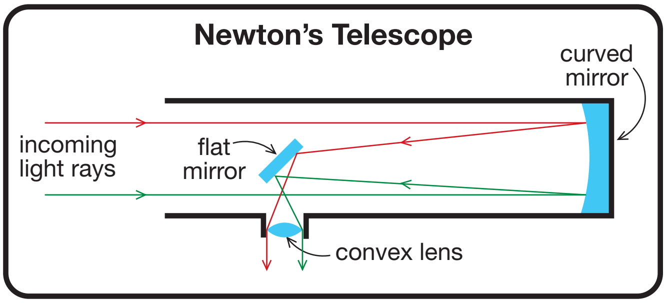
resolution: the amount of small detail visible in an image; low resolution means only large features can be seen, while high resolution means that small details can be seen

Newton's Reflecting Telescope

While Galileo's telescope was designed using lenses based upon the principles of refraction, Isaac Newton improved the magnifying ability of the telescope with a new design that featured a curved mirror that utilized the principles of reflection.

The reflecting telescope has a number of advantages over refracting telescopes:

- A lens can have the same effect as a prism, causing white light to separate into its component colours. This can distort images observed through a refracting telescope, causing some objects to appear to be surrounded by a rainbow. Mirrors do not have this disadvantage.
- Reflecting telescopes can be made with very large openings. Since the light does not pass through the mirror, but bounces off its top surface, a very large curved mirror can be supported from underneath so that it maintains its ideal shape.



Modern Reflecting Telescopes

The Canada-France-Hawaii Telescope, or CFHT for short, is one of the world's largest reflecting telescopes, using a mirror that is 3.6 m in diameter. This telescope is located on top of a dormant volcano in Hawaii because the atmosphere above this high-altitude site is clear, dry, and stable most nights of the year.

Astronomers who study distant stars with this telescope not only consider the brightness and colour of the light they collect, they also use special instruments to measure the polarization of the starlight. Research in this area indicates that the degree to which the starlight is polarized is an indicator of the state of interstellar magnetic fields at the point of origin. Evidence also suggests that starlight can become polarized as it passes through clouds of interstellar dust. Research into the polarization of starlight provides information about stars and the space surrounding them that could not be obtained any other way.

Figure C2.27: Canada-France-Hawaii Telescope

Practice

31. Figure C2.28 shows a telescope that was designed by Johann Kepler.
    a. Is Kepler's telescope a refracting telescope or a reflecting telescope?
    b. Carefully compare the light rays in this telescope to the light rays in Galileo's telescope. Determine a disadvantage of Kepler's design.

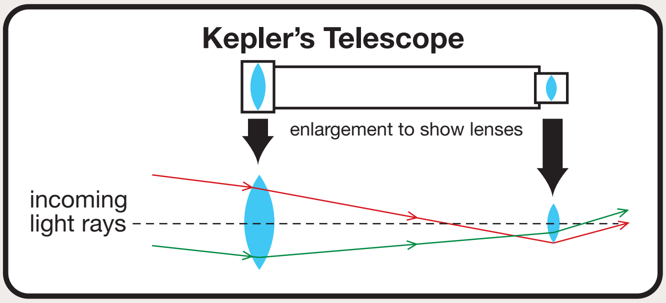


Figure C2.28

32. Explain the following statement:
    The eyes of an eagle have unusually large pupils, which allow the eagle to see the small details in distant objects.

False-Colour Images


Figure C2.29: This photograph was taken with an infrared camera.

Although humans can detect infrared radiation with nerve endings in their skin, it is not possible to detect this radiation with their eyes because the specialized cells located on the retina only respond to the visible spectrum. However, special detectors can transform the patterns made by infrared photons into electrical signals. The electrical signals can then be used to produce a visual image that can be detected by the eyes. The image in Figure C2.29 was made using this process. The white and yellow areas correspond to the places emitting the most infrared radiation, while the darker blue and black areas indicate the places emitting the least infrared radiation. An image like this is called a **false-colour image** because the colours do not correspond to what a person would normally see with his or her eyes. As you'll see in the next activity, false-colour images can be used to make observations of radiation that is normally invisible.

false-colour image: an image that depicts an object in colours that differ from how a person would see the same object using only his or her eyes; often used to produce images using EMR outside of the visible spectrum

Try This Activity

Seeing the Invisible

Science Skills
✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will observe false-colour images using a digital camera and an infrared remote control.

Materials

- digital camera
- infrared remote control

Procedure and Observations

step 1: Point the infrared remote control at your eyes and observe the lens at the end of the remote control as you press several buttons. Record your observations.

step 2: Repeat step 1, but this time view the lens at the end of the remote control using the screen of a digital camera that has been turned on. Record your observations.

Analysis

1. Produce a simple flowchart to summarize the energy transformations that occur from the infrared photons entering the lens of the digital camera to the visible light photons leaving the camera's screen.
2. Refer to your answer to question 1 to explain why it is misleading to say that a person can "see" infrared radiation with a digital camera.

Multiwavelength Astronomy

Another advantage of reflecting telescopes is that there is no large lens to absorb some of the incoming infrared and ultraviolet radiation. This means that reflecting telescopes can be used to gather infrared and ultraviolet radiation as well. The Canada-France-Hawaii Telescope is used to observe the infrared radiation emitted from objects in space on nights when moonlight makes it unfavourable for observations of the visible spectrum. The only place better for infrared astronomy than the high-altitude observatories on Earth is in orbit, high above the distortion and filtering that occurs as the radiation passes through the atmosphere.

The *Hubble Space Telescope*, or HST for short, is able to gather infrared and ultraviolet radiation, in addition to visible light, from its orbit about 600 km above Earth. Although huge clouds of interstellar gas and dust can obscure part of the visible universe, these clouds are transparent to infrared radiation. Since most of the radiation emitted by interstellar matter, planets, comets, and asteroids is in the infrared region of the electromagnetic spectrum, infrared radiation supplies astronomers with information they could not get any other way. In fact, each type of electromagnetic radiation provides astronomers with unique information. This is the reason why astronomers will often study an object using many different types of EMR, an approach known as **multiwavelength astronomy**. Since there is such a range in the wavelengths of EMR, the types of telescopes used at the low- and high-energy ends of the electromagnetic spectrum are quite different.

Figure C2.30: The *Hubble Space Telescope* collects visible light, infrared radiation, and ultraviolet radiation.

Recall that radio waves are the EMR with the largest wavelength and the lowest energy content; so, if astronomers are going to gather this radiation, it requires an enormous dish to reflect the waves to a detector. The fact that radio waves have a very long wavelength means that diffraction can create significant difficulties with resolution if two sources of radio waves are very close together. The solution in these cases is to make the effective size of the opening of a telescope even larger by collecting data from a group of radio telescopes that are linked together. One arrangement that addresses this problem is called a **very large array**. This array simultaneously collects data from a number of individual radio telescopes, which is then processed by computers to produce a single image.

Figure C2.31: This radio telescope uses a 43-m dish to collect radio-wave data.

Figure C2.32: This very large array in New Mexico consists of 27 individual radio telescopes. Each arm of the array, consisting of nine telescopes, can be up to 20 km long.

multiwavelength astronomy: the study of objects in space using the principle that these objects reveal different aspects of their behaviour through the many wavelengths of EMR they emit

very large array: a group of radio telescopes distributed over many kilometres along the arms of a Y-shaped track

You will recall from your work earlier in this chapter that types of radiation from the middle of the electromagnetic spectrum are unique in that they can effectively demonstrate both wave characteristics and photon characteristics. This is why visible light can be refracted as a wave as it enters the lenses of a digital camera, and then the light can interact with individual atoms as its photons collide with the camera's sensor. For high-energy radiation, like X-rays and gamma rays, the photon properties tend to dominate, while the wave properties are more difficult to observe. This creates design challenges for astronomers gathering X-ray and gamma radiation.

The *Chandra* X-ray telescope cannot use a large curved mirror at the end opposite the opening because the penetrating ability of the X-rays would cause the radiation to pass through the mirror instead of bouncing off its surface. Mirrors are still used, but in this case they are arranged along the inside of the body tube of the telescope. X-rays will only reflect if the direction of the radiation is almost parallel to the surface of the specially designed mirror. *Chandra* is a good example of how astronomers have to take into account the properties of the radiation that they want to collect when they design their instruments. As Figure C2.34 indicates, the wave properties of reflection, refraction, and diffraction are more difficult to observe at the high-energy end of the electromagnetic spectrum.

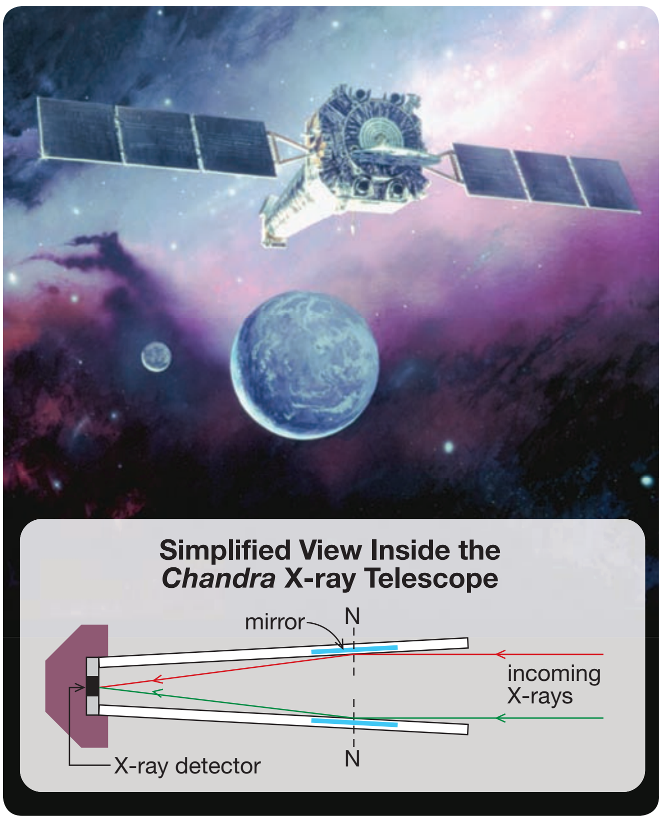


Figure C2.33: *Chandra* is a space-based telescope that uses mirrors along the inside of the body tube to focus incoming X-ray radiation.

Despite these differences, there are characteristics astronomers can measure from all regions of the electromagnetic spectrum: energy content, wavelength, frequency, degree of polarization, and speed.

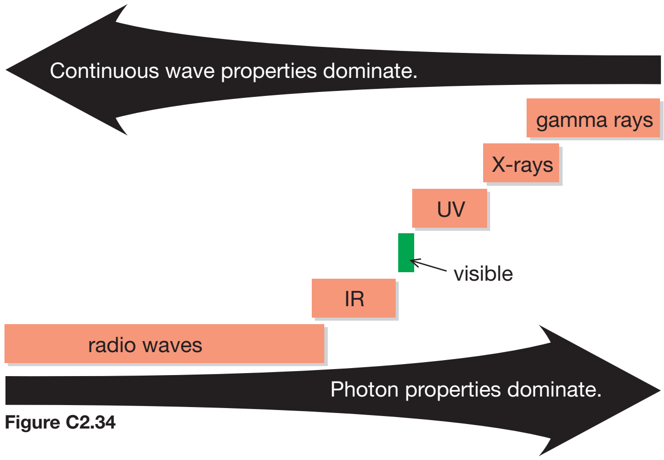


Figure C2.34

Utilizing Technology

Tracking Space-Based Telescopes and Other Satellites

Science Skills
✓ Performing and Recording
✓ Analyzing and Interpreting

Purpose

You will use computer software available from a NASA website to compare the orbits of space-based telescopes and other satellites.

Procedure

Obtain the handout "Tracking Space-Based Telescopes and Other Satellites" from the Science 30 Textbook CD. Follow the instructions on the handout to find the Internet site and then collect the data from this site.

Analysis

Concisely explain how Earth is able to exert gravitational force on a fast-moving satellite so that it maintains an orbit around the planet.

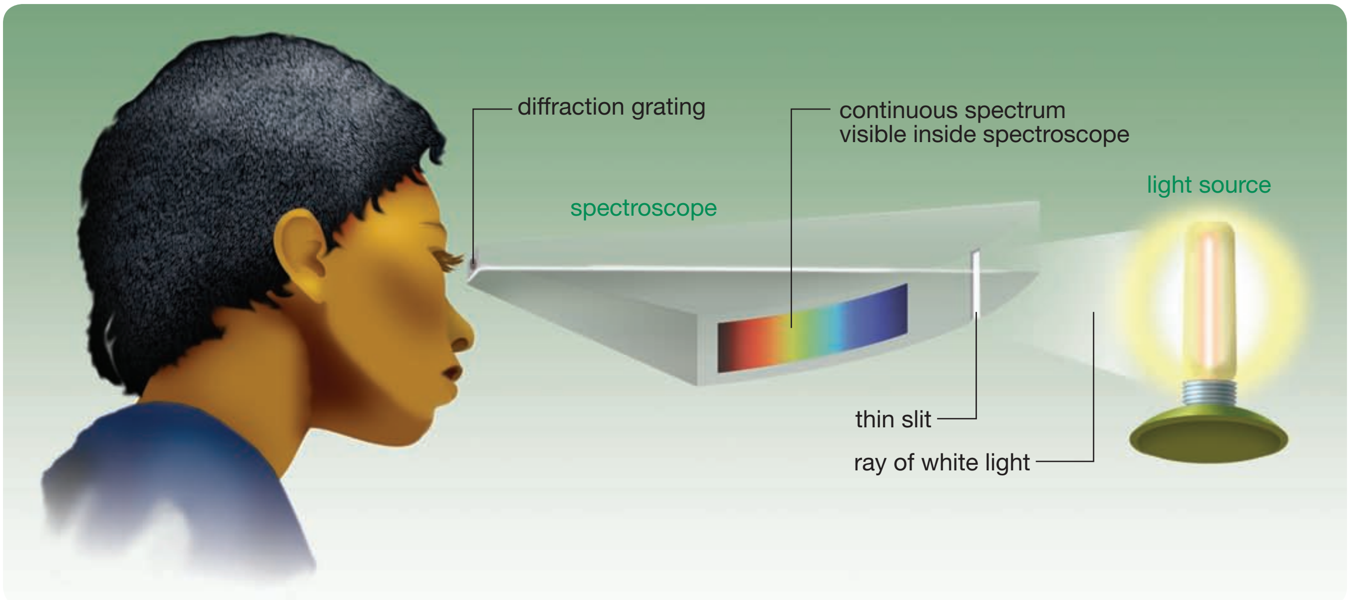
Practice

33. Explain why astronomical observatories for infrared radiation are sometimes located in specially outfitted aircraft that can fly at high altitudes.
34. Explain why radio telescopes are so large.

Analyzing Starlight

Given the challenges of gathering EMR with telescopes, astronomers take great care to thoroughly analyze the radiation data they collect. One technique is to use a prism to separate the radiation into its component wavelengths. This can also be done with a **diffraction grating**. A diffraction grating is a piece of glass or plastic with thousands of tightly spaced parallel lines etched on its surface.

diffraction grating: a piece of glass or plastic with thousands of tightly spaced lines etched on its surface; used to produce spectra

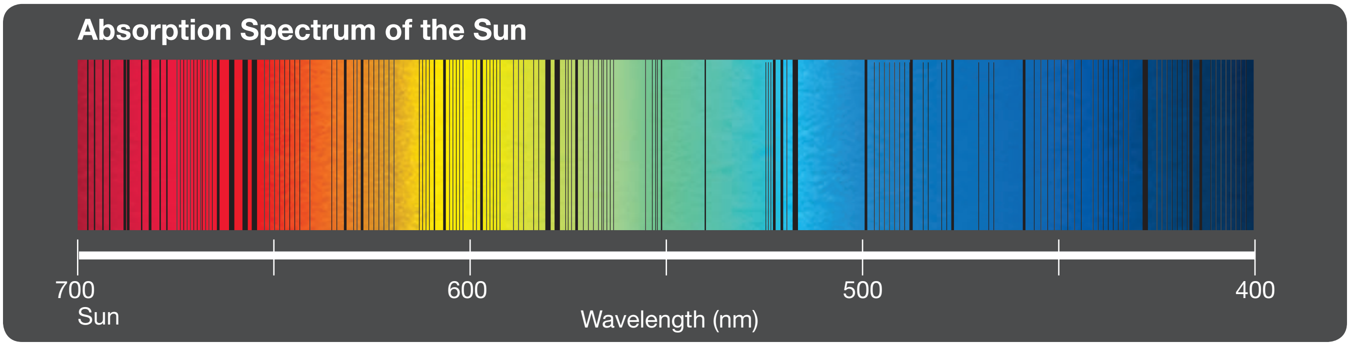


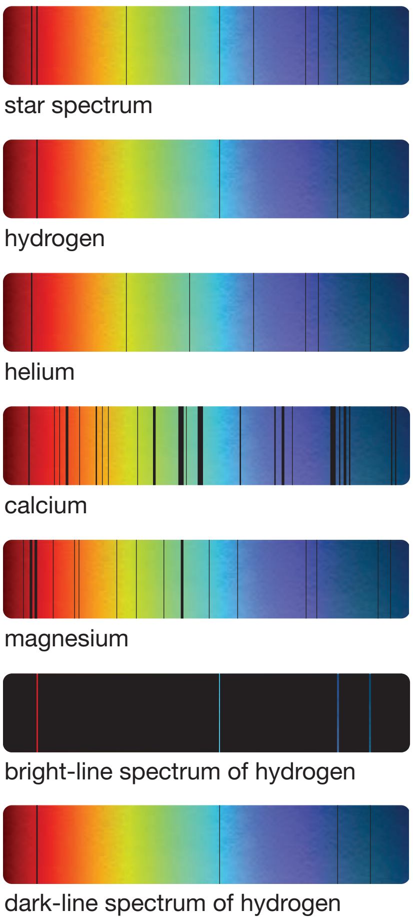
If the source of the EMR is a dense material heated to about 6000°C, most of the radiation emitted is from the visible spectrum. Since the resulting rainbow of colour is continuous, with one colour blending into another, this spectrum is called a **continuous spectrum**. This is what would be observed if it were possible to send a probe carrying a prism or a diffraction grating to the surface of the Sun. This kind of spectrum is not observed by probes that are beyond the Sun's atmosphere because the gases in the cooler parts of the Sun's outer atmosphere absorb certain wavelengths of light. Each wavelength that is absorbed corresponds to a dark line on the rainbow of colours.

continuous spectrum: a spectrum having no distinct lines that is distributed over an unbroken band of wavelengths

Since each dark line corresponds to a wavelength of radiation that has been absorbed, this is called a **dark-line spectrum** or an **absorption spectrum**. The atoms of a particular element in a low-pressure gas will only absorb certain wavelengths, creating a dark-line spectrum that is unique to that gas. This is a very useful property for astronomers because the dark-line spectrum acts like a fingerprint, allowing astronomers to identify the presence of certain atoms in the atmosphere of the Sun based on the patterns of dark lines.

absorption spectrum or dark-line spectrum: a spectrum that has a pattern of dark lines due to the light passing through an absorbing medium; can be used to identify a material



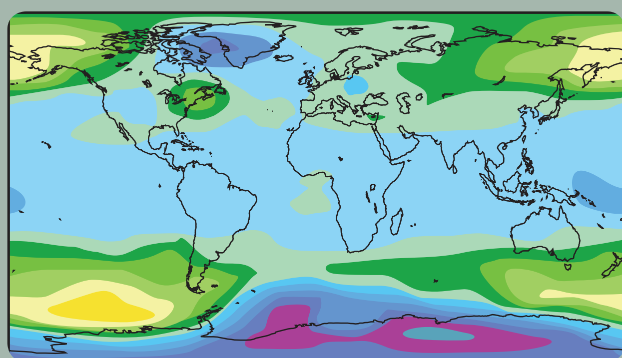


This fingerprinting idea can be taken one step further when an electric current is forced to pass through a low-pressure gas. In this case, the same wavelengths that the gas absorbs when light passes through it are emitted when the atoms of the gas are excited to higher energy levels. This spectrum of a few separated wavelengths is called an **emission spectrum** or a **bright-line spectrum**.

Both emission and absorption **spectra** are normally analyzed with a diffraction grating mounted on a device that enables an observer to determine the wavelength of each emitted line. Such a device is called a **spectrometer**, since it allows precise measurements of the absorbed wavelengths in a spectrum to be made.

Since only certain wavelengths are emitted, this pattern is called an emission spectrum or a bright-line spectrum. In the next investigation you will have an opportunity to use a spectroscope to observe and record the emission spectra for a number of different gases.

Science Links: Thickness of the Ozone Layer



Ultraviolet light from the Sun can be reflected from Earth back into space. Spectrometers on satellites use this reflected UV radiation to produce an absorption spectrum. This data is then analyzed to determine the thickness of the ozone layer. The connections among ultraviolet light, the thickness of the ozone layer, and the release of CFCs into the atmosphere was explored in Unit B.

emission spectrum or bright-line spectrum: a spectrum that has a pattern of separate bright lines that is emitted from an excited gas under low pressure; can be used to identify a material

spectra: plural form of *spectrum*

spectrometer: an optical instrument that is used to measure the wavelengths of light

Investigation

Observing Spectra

Purpose

You will use a spectroscope to record the patterns of wavelengths emitted by excited atoms in a gas-discharge tube and by the wavelengths emitted by the hot filament of a light bulb.

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

Materials

- handheld spectroscope
- high-voltage power supply that can run gas-discharge tubes
- gas-discharge tubes for different gases (hydrogen, helium, mercury, and neon)
- showcase light bulb mounted in a lamp with a dimmer switch
- standard fluorescent tube light source (often used as ceiling lighting for classrooms and kitchens)
- coloured pens or pencils
- "Observing Continuous and Emission Spectra" handout

CAUTION!

- The gas-discharge tubes can become hot after running for a few minutes. Switch off the power and let the bulb cool before handling.
- The high-voltage power supply represents a significant shock hazard. Be sure it is switched off when changing bulbs.

Part A: Observing a Continuous Spectrum

Procedure and Observations

step 1: Switch on the showcase bulb and adjust the dimmer switch so the bulb is bright. Observe the spectrum produced by the bulb by looking through the spectroscope. Note the relative brightness of each of the colours seen through the spectroscope. Use coloured pens or pencils to record your results.

step 2: Use the dimmer switch to gradually reduce the bulb's brightness. Note the changes in the relative brightness of each of the colours seen through the spectroscope. Record your results.

Analysis

1. Describe the differences between the spectra produced by the bulb on maximum brightness and the bulb on a dim setting.

Part B: Observing Emission Spectra

Procedure and Observations

step 1: Obtain the handout "Observing Continuous and Emission Spectra" from the Science 30 Textbook CD.

step 2: Connect the gas-discharge tube containing neon gas to the power supply. Switch on the power supply and dim the lights in the room. Observe the light from the tube through the spectroscope. Use coloured pens or pencils to record your results on the handout. Switch off the power supply.

step 3: Repeat step 2 for mercury, helium, and hydrogen. In each case, record your results on the handout.

Analysis

2. The unaided eye sees each of the gas-discharge tubes as producing one colour of light, while the spectroscope reveals a number of separate bright lines. Speculate on how the human eye arrives at one colour from all the colours produced by a gas-discharge tube.

Part C: Applications

Procedure and Observations

Using a spectroscope, observe the light produced by a standard fluorescent tube light source. Note the wavelengths of the bright lines produced in the middle of the spectrum. Record your results.

Analysis

3. Use your data from Part B to determine the type of excited gas inside a standard fluorescent tube.

How Astronomers Analyze Spectra

One way starlight can be analyzed is to determine the chemical composition of the clouds of cool gases found in a star's outer atmosphere. In the next activity you will have an opportunity to see how this is done as you review what you learned about spectra.

Utilizing Technology

Spectral Analysis

Purpose

You will use the applet called "Spectral Analysis" to learn how astronomers analyze starlight to determine the chemical composition of stars.

Science Skills

✓ Performing and Recording
✓ Analyzing and Interpreting

Procedure

step 1: Locate the applet "Spectral Analysis" on the Science 30 Textbook CD.

step 2: Follow the instructions on the application to complete this activity.

Doppler Shift

Think back to the last time you were passed by an emergency vehicle with its siren wailing. Recall the change in pitch that occurred as the siren approached you and then as it passed by. Figure C2.35 compares an observer's experience with sound waves emitted from a stationary source with the sound waves emitted from a moving source. If the source is moving towards the observer, the incoming waves get bunched together, resulting in an apparent higher-frequency wave than what is experienced from a stationary source. If the source is moving away from the observer, the incoming waves get spaced farther apart, resulting in an apparent lower-frequency wave than experienced from a stationary source. This shift in the frequency of a wave due to relative motion between the observer and the source is called the **Doppler effect**.

This same effect can occur with the electromagnetic radiation emitted by stars as they move relative to observers on Earth. In the case of EMR, a shift to higher frequencies is called a **blue shift** and occurs when stars are moving toward an observer. A **red shift** in EMR occurs when a star is moving away from an observer. In the next activity you will have an opportunity to learn more about how astronomers use the Doppler effect to determine the motion of distant stars relative to Earth.

Doppler effect: a change in the observed frequency of a wave due to motion between the source and the observer

blue shift: an increase in frequency due to a source of EMR moving toward an observer, due to the Doppler effect

red shift: a decrease in frequency due to a source of EMR moving away from an observer, due to the Doppler effect

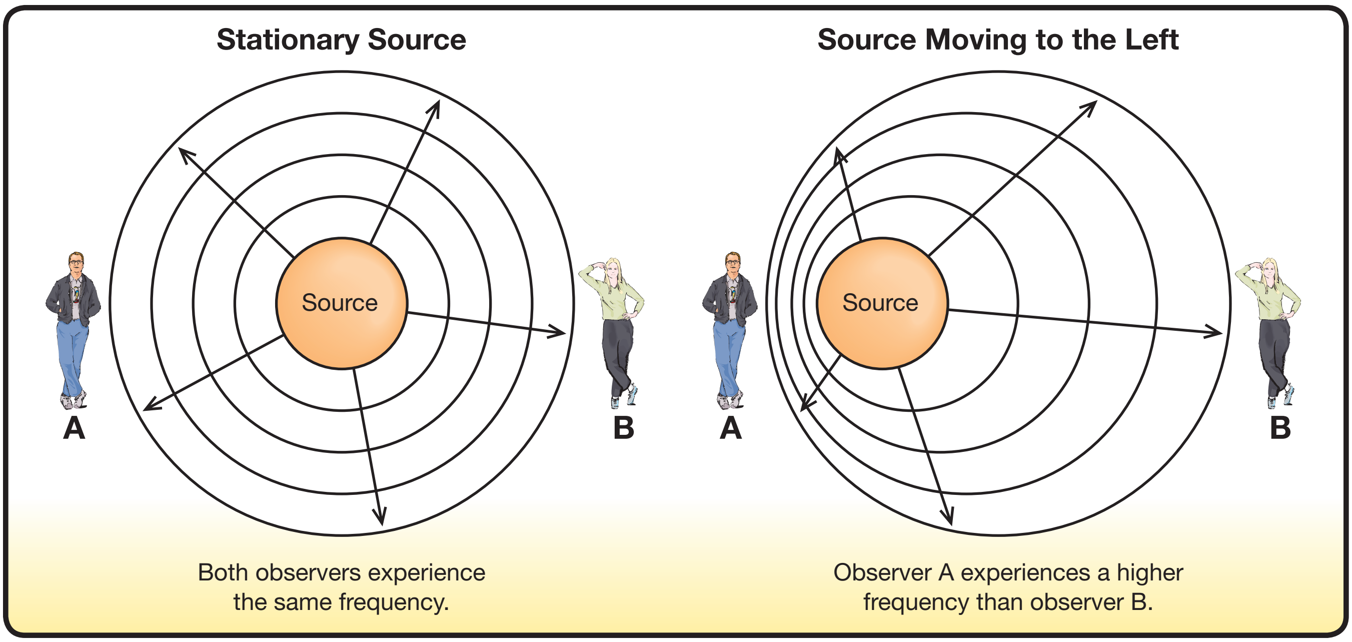


Figure C2.35

Utilizing Technology

Red Shift

Purpose

You will use the applet "Red Shift" to learn how astronomers apply the Doppler effect to starlight to determine the motion of stars relative to Earth.

Science Skills

✓ Performing and Recording

✓ Analyzing and Interpreting

Procedure

step 1: Locate the applet "Red Shift" on the Science 30 Textbook CD.

step 2: Follow the instructions on the application to complete this acitivity.

Practice

35. Explain the differences between an emission spectrum, an absorption spectrum, and a continuous spectrum.

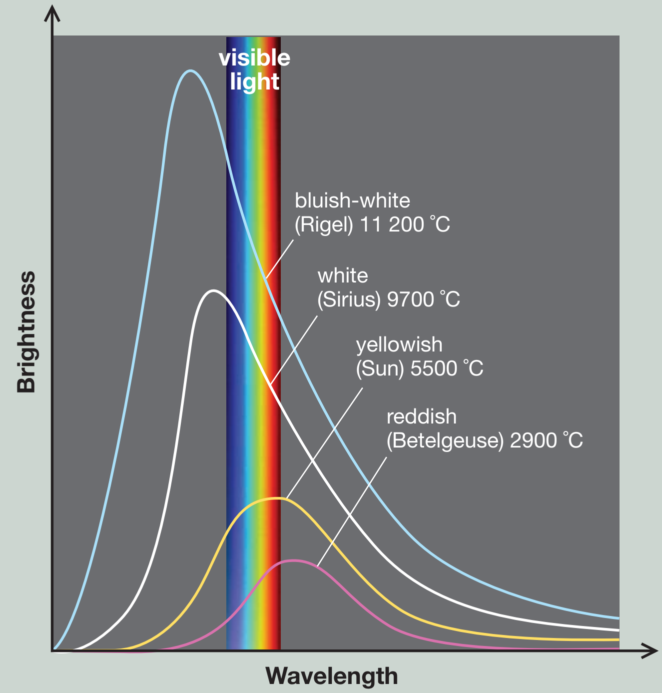
36. Every remote galaxy in the universe has red-shifted light. Explain how this evidence supports the idea that the universe is expanding.

Classification of Stars

In an earlier investigation, you analyzed the spectra produced by a light bulb in a lamp with a dimmer switch. Using more sophisticated equipment, researchers have conducted similar experiments by measuring the temperature of the object emitting the light and then carefully recording the spectra produced. The patterns from these investigations give astronomers a powerful tool because they can work backward by using the spectra to determine the surface temperature of stars. Although there will be dark lines in these spectra, if the brightness of the emitted light is plotted against wavelength, interesting patterns emerge.

If the peak of the continuous spectrum occurs with wavelengths slightly longer than red light (in the infrared region), the star likely has a surface temperature of about 2900ºC. This is why a star like Betelgeuse appears red to the unaided eye. As the peak of the emitted light shifts to shorter wavelengths and increases to greater brightness, the surface temperature of the star increases. Notice that very hot stars, like Rigel, have their peak in the ultraviolet region of the electromagnetic spectrum. Although your eye would interpret this as a bluish-white colour, most of the emitted radiation is in the ultraviolet region. Note that the connection between temperature and emitted radiation is consistent with your earlier work with the surface of the Sun.

The Continuous Spectra of Stars: Brightness of Emitted Light Versus Wavelength



Evolution of Stars

Given the variation in the colour and brightness of the light emitted by stars, it is natural to wonder why these variations occur. Current theories explain the spectra of a particular star in terms of the star's mass and its stage in stellar evolution. Although all stars form in regions rich in hydrogen gas and dust, the stages of evolution depend on the original mass of the star.

Evolution of Low-Mass Stars

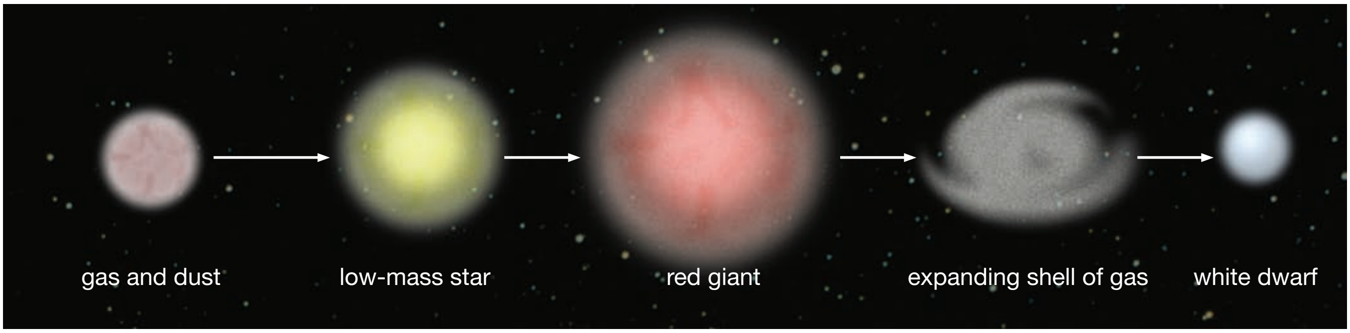


Figure C2.36: The mass of a low-mass star is between 0.1 and 1.4 solar masses.

- **red giant:** a star of great size and age that has a relatively low surface temperature
- **nebula:** an interstellar cloud of gas and dust
- **white dwarf:** a compact star found as the last stage in the evolution of low-mass stars
- **supernova:** a stellar explosion that produces a very bright cloud of ionized gas that remains a very bright object in the sky for weeks or months
- **neutron star:** a super-dense star consisting mainly of neutrons formed as the last stage in the stellar evolution of intermediate-mass stars
- **pulsar:** a rotating neutron star that emits radiation in regular pulses

Small stars are those stars that have a mass less than 1.4 times the mass of the Sun. These stars begin when gravitational attraction causes gas and dust to collect. Once the core temperature of the gathering mass reaches about 10 000 000°C, nuclear fusion reactions begin and the star is born. The Sun is an example of a low-mass star. Astronomers suspect that the Sun's hydrogen fuel will be exhausted in about 5 billion years. According to this theory, the core will collapse while the outer layers expand, transforming the Sun into a **red giant**. Betelgeuse is an example of a star in this stage of its evolution. In the final stages of evolution, the core temperature rises and the outer layers are thrown off as an expanding shell of gas called a **nebula**. All that remains of the original star is its core, which has exhausted its nuclear fuel. A star in this stage is called a **white dwarf** because it is a small source of dim white light.

If the mass of the starting matter is between 1.4 and 8 times the Sun's mass, the process of stellar evolution happens more quickly. Astronomers suspect that the additional mass means that a supergiant with a core temperature of about 3 000 000 000°C will form. They think that the next steps result in the core imploding, followed by a rebound explosion called a **supernova**. Most of the stellar material is hurled into space, leaving behind a super-dense object called a **neutron star**. A neutron star is thought to spin very rapidly on its axis, emitting radio waves. In some cases, neutron stars emit radio waves as pulses, which is why this kind of source is called a **pulsar**. A pulsar in the Crab Nebula is thought to be the remains of a supernova explosion that was visible from Earth in the year 1054.

Evolution of Intermediate-Mass Stars

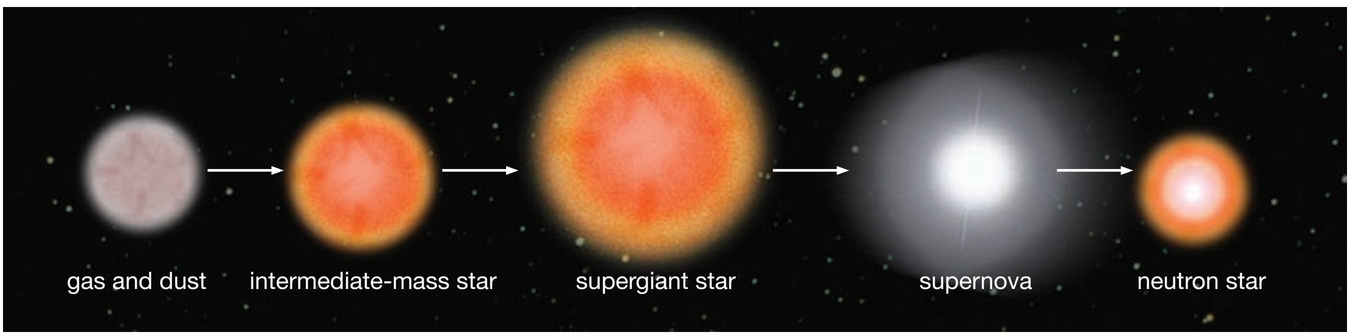


Figure C2.37: The mass of an intermediate-mass star is between 1.4 and 8 solar masses.

If the mass of the star is greater than 8 solar masses, when the core of the supergiant implodes, the result is not a supernova. Instead, the core continues to collapse, becoming more and more dense. Eventually the gravitational field of this incredibly dense matter is so great that not even light can escape. The result is called a **black hole** because no electromagnetic radiation is emitted while this object consumes surrounding matter.

black hole: an area in space with a gravitational field so strong that neither matter nor EMR can escape; formed as the last stage in the evolution of high-mass stars

Evolution of High-Mass Stars

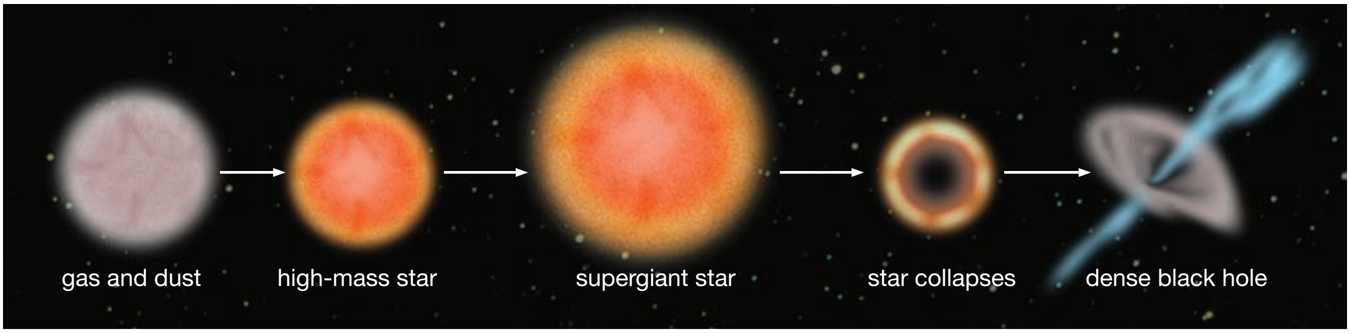


Figure C2.38: The mass of a high-mass star is greater than 8 solar masses.

Practice

37. Suppose two new stars are discovered. One star appears to emit light that is slightly less yellow and more white than the light emitted by the Sun. The other star appears to emit light that is more orange than the light emitted by the Sun. Use this information to compare the temperature of each star to the Sun.

38. The final object that a star becomes in stellar evolution is either a white dwarf, a neutron star, or a black hole. Identify the feature of a star that determines what its endpoint will be in stellar evolution.

39. Explain why it is impossible to view a black hole through a telescope.

Utilizing Technology

Risks and Benefits of Deep-Space Probes

Science Skills
✓ Initiating and Planning
✓ Performing and Recording
✓ Analyzing and Interpreting
✓ Communication and Teamwork

Background Information

Unpiloted spacecraft that collect data from the planets and other objects that lie beyond the orbit of Mars are called “deep-space probes” because the distances from Earth to these objects are so large. The *Cassini-Huygens* probe that was sent to Saturn certainly meets this criteria because Saturn is about twice as far from the Sun as is Jupiter and nearly ten times farther from the Sun than Earth is.

Purpose

You will use the Internet as a research tool to assess the risks and benefits of the *Cassini-Huygens* deep-space probe that was sent to Saturn.

Research Procedure

Use the information from NASA, the European Space Agency, the Italian Space Agency, and other websites to help answer the following questions.

1. The *Cassini-Huygens* deep-space probe was not launched from Earth on a direct path to Saturn. Instead, its path involved looping around the Sun twice using a technique called “gravity assist” before moving toward the outer parts of the solar system.

a. Explain what is meant by “gravity assist” and why this was necessary for the *Cassini-Huygens* deep-space probe.

b. Use a diagram to describe the path taken by the *Cassini-Huygens* deep-space probe on its way from Earth to Saturn.

2. On June 30, 2004, the *Cassini-Huygens* deep-space probe entered Saturn's orbit and began to collect data that was transmitted back to Earth. Use a table to describe some of the instruments onboard *Cassini* that were used to collect data using EMR. Record the research focus for each instrument as well as the wavelengths detected and the region of the electromagnetic spectrum that was sampled.
3. In January 2005, the *Huygens* probe separated from *Cassini*. The *Huygens* probe then dropped into the atmosphere of Titan, one of Saturn's moons, and collected data as it descended and as it sat on the surface.
   a. Explain why scientists were so interested to collect data from Titan.
   b. Describe some of the findings from this research.
4. None of the instruments onboard the *Cassini-Huygens* deep-space probe could collect data or send data back to Earth without a source of electrical energy. This energy was provided by three radioscopic thermoelectric generators, or RTGs for short, which convert heat from the natural radioactive decay of plutonium dioxide into electricity. The mass of PuO_2(s) on board *Cassini-Huygens* is about 33 kg.
   a. Explain why photovoltaic cells would not be a practical way to generate electrical energy for the *Cassini-Huygens* deep-space probe.
   b. Plutonium dioxide is highly toxic, since it is a potent source of ionizing radiation. Even a few grains of PuO_2(s) dust lodged in the lungs can cause cancer.
      i. Explain why some of the residents living close to the launch site for the *Cassini-Huygens* deep-space probe wanted the launch of this probe cancelled.
      ii. Explain why some environmentalists in several countries protested the gravity-assist flyby of the *Cassini-Huygens* deep-space probe.

Analyzing the Issue

5. a. Analyze the results of your research by concisely organizing your findings in a table, with "Risks" at the top of one column and "Benefits" at the top of the other.
   b. Review the lists of risks and benefits from the point of view of the stakeholders. How would residents living close to the launch site, environmentalists in other countries, and scientists who were going to use the data from *Cassini-Huygens* each react to the entries on your lists?

Taking a Stand and Defending Your Position

6. Do the benefits of a deep-space probe, like *Cassini-Huygens*, outweigh the risks? Take a clear position on this issue by writing a few concise paragraphs. Your position should be supported by the body of research and should indicate that you have considered the question from more than one viewpoint.

Evaluation

7. It is very helpful at this stage to share your findings with others. How do their points of view differ from yours? Are the arguments made to support these views consistent with the information you researched? Did other students find additional information that was unknown to you? How has your position changed since you started? If you had to make this decision again, what would you have done differently?

2.2 Summary

Some people say that astronomy is the oldest science because humans have been looking into the sky for many thousands of years. In the beginning, the light from stars was used to help with navigation, to tell time, and to predict the seasons. Now, starlight is also used to determine the chemical composition of stars, the motion of stars relative to Earth, and the temperature on the surface of stars.

In addition to visible light, other forms of EMR are emitted by objects beyond Earth. The fact that each type of radiation can provide unique information about the source is the basis for multiwavelength astronomy.

2.2 Questions

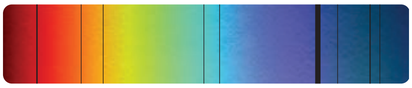
Knowledge

1. Obtain the handout "Summarizing Multiwavelength Astronomy" from the Science 30 Textbook CD. Complete this handout by adding the necessary information to each column.

Applying Concepts

Obtain the handout "Reference Absorption Spectra" from the Science 30 Textbook CD. Use the information on this handout to answer questions 2 and 3.

2. Often a spectrum will contain the lines of more than one excited gas. Identify the two gases that produced the following spectrum.



3. Describe the effect on the pattern of spectral lines observed on Earth if a star is moving away from Earth and if a star is moving toward Earth.

Use the following information to answer questions 4, 5, and 6.

Historical records indicate that in the year 1054 an object that glowed as brightly as a full moon appeared in the sky. Archaeological evidence suggests that the ancient Pueblo People (also known as the Anasazi), who lived in what is now Arizona, recorded the appearance of a new star in the sky.

Figure C2.39: Archaeologists suspect the star-like image to the left of the crescent moon is the supernova. The image of the hand is thought to indicate that this site is sacred.

The accounts recorded by people living in Japan and China pinpoint the location of this very bright new object near the constellation Taurus. This same location in the sky is currently the location of a glowing cloud of interstellar gas and dust known as the Crab Nebula.

The current interpretation of all this data is that the Crab Nebula is the remains of a supernova explosion that was observed by people on Earth over 900 years ago.

The Crab Nebula emits EMR from all regions of the electromagnetic spectrum. Figure C2.40 shows images that were produced using visible radiation (VIS), ultraviolet radiation that is near the visible spectrum or near ultraviolet (NUV), ultraviolet radiation that is far from the visible spectrum or far ultraviolet (FUV), and X-ray radiation. Not shown is the data from the radio spectrum, which indicates the presence of a pulsar—a rotating neutron star at the centre of the nebula.

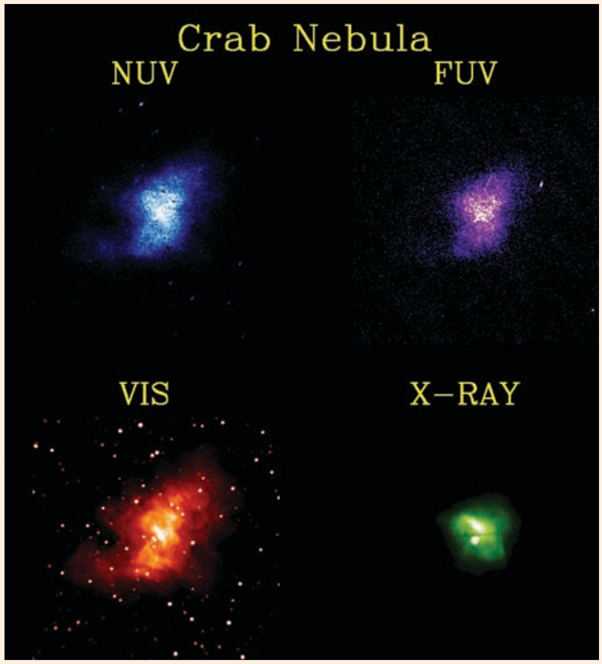


Figure C2.40: Images of the Crab Nebula produced from emitted EMR

4. Describe the stages of evolution for the star that produced the Crab Nebula.

5. Explain why astronomers have collected data for the Crab Nebula using so many different types of EMR.

6. Archaeological evidence suggests that the Anasazi People had an agricultural economy that was centred on corn, beans, and other crops.

   a. Suggest reasons why astronomical observations would have been important to the Anasazi People.

   b. Suggest a reason why the Anasazi People decided to leave a record of this astronomical event.

Chapter 2 Summary

In this chapter you have surveyed each region of the electromagnetic spectrum, from radio waves with wavelengths that can be kilometres long to gamma rays with wavelengths smaller than atoms. The differences in wavelength, frequency, and energy among the different types of electromagnetic radiation account for the variety of interactions that are possible with matter. Examples include visible light being used by a dandelion in photosynthesis and microwaves being beamed from satellites in orbit to satellite dishes on Earth's surface. Clearly, EMR plays a key role in living systems and in the growing number of high-tech devices that are used in daily life.

People have utilized the visible radiation from stars in the form of constellations for thousands of years. Inuit people use this EMR for navigation, for telling time, and for predicting changes in the seasons. Modern astronomers have developed technologies that allow them to use radiation from across the whole electromagnetic spectrum as they study stars and other objects beyond Earth.

Summarize Your Learning

In Chapter 2 you learned a number of new terms, processes, and theories. Many of the concepts are related, and you will have an easier time recalling them if they are organized into patterns.

Since the patterns have to be meaningful to you, there are some options about how you can create this summary. Each of the following options is described in "Summarize Your Learning Activities" in the Reference Section. Choose one of these options to create a summary of the key concepts and important terms in Chapter 2.

Option 1: Draw a concept map or a web diagram.	**Option 2:** Create a point-form summary.	**Option 3:** Write a story using key terms and concepts.	**Option 4:** Create a colourful poster.	**Option 5:** Build a model.	**Option 6:** Write a script for a skit (a mock news report).

Chapter 2 Review Questions

Knowledge

1. In Chapter 2 you saw how each region of the electromagnetic spectrum is applied to technologies on Earth and to the study of astronomy. In many cases, the penetrating ability of the radiation plays a significant role in how the radiation is used. Copy and complete the following table to summarize what you have learned.

APPLICATIONS OF ELECTROMAGNETIC RADIATION

Region of Electromagnetic Spectrum		Applications on Earth That Illustrate Penetrating Ability		Applications in Astronomy That Illustrate Penetrating Ability	
Type of EMR	**Range of Frequencies**				
radio waves					
microwaves					
infrared radiation					
visible light					
UV radiation					
X-rays					
gamma rays					

2. Some forms of EMR are classified as ionizing radiation.
   a. Explain the meaning of this term.
   b. Describe the effects ionizing radiation has on living tissue.
   c. Describe strategies you can use to reduce your exposure to ionizing radiation.
3. One way to analyze EMR is to pass the radiation through a prism or a diffraction grating. This causes the radiation to separate into its component wavelengths, producing a spectrum. Depending upon the source, three types of spectra can be observed. For each of the following types of spectra, describe a possible source and indicate how this information could be used by astronomers.
   a. continuous spectrum
   b. absorption spectrum (dark-line spectrum)
   c. emission spectrum (bright-line spectrum)
4. Sketch a series of diagrams to show the main steps in the evolution of stars like the Sun.
5. A black hole is one of the most intriguing regions of space studied by astronomers.
   a. Describe some of the characteristics of a black hole.
   b. Describe how a black hole is formed.

Applying Concepts

6. In astronomy, the unit that is often used to describe distances between Earth and stars other than the Sun is the light-year. For example, Alpha Centauri (after the Sun, the closest star to Earth that can be seen with the naked eye) is 4.3 light-years from Earth.
   a. Determine how many metres there are in one light-year.
   b. Use your answer to question 6.a. to determine the distance (in metres) from Alpha Centauri to Earth.
   c. Explain the following statement:

      If you were to see Alpha Centauri on a clear night, you would not be seeing the way this star looks now. You would be seeing the way it looked 4.3 years ago.

   d. Sirius is the brightest star in the night sky and is located 8.3×10^{16} m from Earth. When you look at Sirius in the night sky, how far back in time are you actually seeing it?
7. A truck driver uses a citizen's band, or CB, radio to communicate with other truckers. If the broadcast frequency is 27.965 MHz, calculate the wavelength of the radio wave.
8. Figure C2.41 shows the wavelengths of light that are absorbed by pigments in the chloroplasts of plants.
   a. Identify the wavelengths of light that are strongly absorbed by all three pigments.
   b. Identify the wavelengths of light that are not strongly absorbed by these three pigments.
   c. If you looked at a plant leaf that contained these three pigments, what would be the colour of the leaf? Explain your answer.

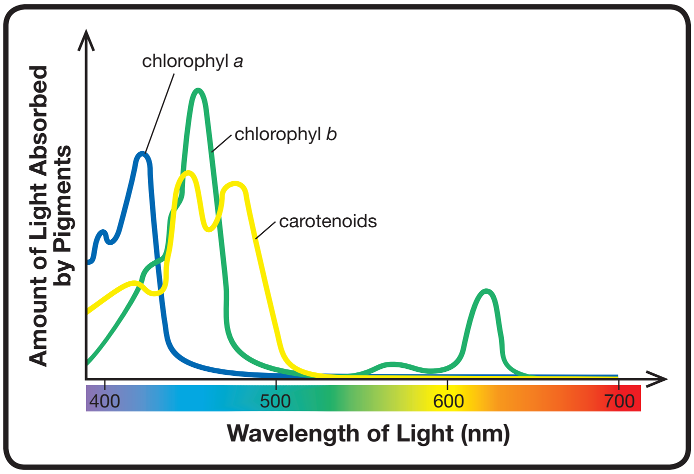


Figure C2.41

9. The world's largest airborne astronomical observatory is NASA's Stratospheric Observatory for Infrared Astronomy, or SOFIA for short. In Figure C2.42, the black square near the tail shows where the open cavity for the telescope is located.

Figure C2.42

   a. Explain why it is necessary to go more than 10 km above Earth's surface to make observations in the infrared and microwave regions of the electromagnetic spectrum.
   b. What specific astronomical phenomena is SOFIA designed to study? You can answer this question by using the Internet as a research tool to find out the key objectives on NASA's SOFIA website. To find the website, enter the following keywords into your Internet seach engine: *NASA + SOFIA*.

Use the following information to answer questions 10 to 13.

There has been a dramatic increase in the number of devices in homes and workplaces that utilize radio waves to make connections between devices. These devices are very convenient because they eliminate the need for cables to carry signals. This is why they are sometimes called "wireless radio" technologies. Two of the most common wireless radio technologies are cordless telephones and wireless routers that enable more than one computer to access the Internet using a single modem.

When a new technology is introduced to solve one problem, a new set of unintended problems is often created.

10. The fact that you can listen to a portable radio inside most buildings illustrates an important property of radio waves—the ability to penetrate walls made of wood, cement, and glass.

a. Explain why this property of radio waves is essential to the design of wireless devices.

b. Explain how this property of radio waves can create security issues when wireless devices are used to communicate sensitive information, such as credit card numbers or passwords for bank cards.

c. Explain why businesses that use wireless communication systems reduce the power of their transmitters to the minimum level necessary to run all the devices within the building.

11. The owner's manual for a wireless router includes the following recommendations for the location of the router:

- Place the wireless router in a central location within a home or business, away from outside walls.
- Avoid placing the wireless router near large metal objects, like filing cabinets.

Use your knowledge of the behaviour of radio waves to explain each of these recommendations.

12. Many brands of cordless telephones use a frequency of 2.4 GHz. This same frequency is also utilized by manufacturers of wireless routers.

a. Explain what the phrase "a frequency of 2.4 GHz" means in terms of the interaction of a radio wave with an antenna.

b. Calculate the wavelength of the radiation associated with this signal.

c. Explain the difficulties that could occur if a person was using a cordless phone while using their computer's wireless router.

d. Suggest some solutions to this problem.

13. Since the number of wireless radio devices is continuing to increase, alternative technologies are being developed. Wireless infrared systems use a beam of infrared radiation to send a signal from one device to another. You utilize a system that transmits infrared signals every time you use a remote control to operate a TV or VCR. Use your experiences with remote controls to outline some of the possible advantages and disadvantages of a wireless infrared communication system.

14. In addition to making astronomical observations, telescopes can also be used for observing objects on Earth. A mounted set of binoculars at Lake Louise gives tourists a magnified view of the glacier at the far end of the lake.

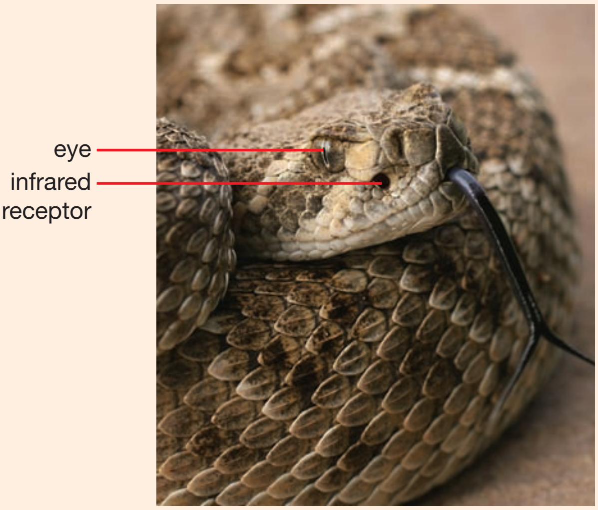
Use Figure C2.43 to determine whether the design of this device is closer to being a reflecting telescope or a refracting telescope.

Figure C2.43: Lake Louise, Alberta

15. X-rays produced in a diagnostic imaging machine have a wavelength of 8.8 nm. Determine the frequency of this radiation.

Use the following information to answer questions 16 and 17.

This diamondback rattlesnake has a pair of infrared receptors on its head, between its eye and its nostril.



To utilize these receptors, the snake moves its head back and forth until the radiation detected by the receptor on the left is equal to the radiation detected by the receptor on the right. When this occurs, the prey emitting the infrared radiation is straight ahead of the snake. This system can guide the snake as it hunts in dark conditions.

16. Diamondbacks are most sensitive to infrared radiation with a wavelength of 10 μm.

a. Calculate the frequency of this radiation.

b. Speculate why snakes have evolved to be sensitive to this frequency of infrared radiation.

17. Draw a diagram to show how a mouse that is straight ahead of a diamondback's head would send equal amounts of infrared radiation to each sensor. Draw another diagram to show how a mouse that is off-centre would send more radiation to one sensor than the other.

Use the following information to answer question 18.

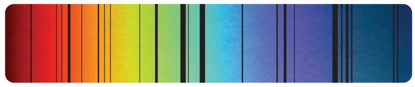
In Chapter 2 you learned of the hazards to living tissue caused by exposure to ionizing radiation. You also learned that health-care professionals go to great efforts to keep the exposure to themselves and their patients as low as reasonably achievable, or ALARA for short.

18. Safety procedures are used to ensure the safety of patients and the technicians who operate X-ray machines. Describe the procedures that are based on ALARA to minimize the risks to patients and to the health-care professionals operating the equipment.

Obtain the handout "Reference Absorption Spectra" from the Science 30 Textbook CD. Use the information on this handout to help answer questions 19 and 20.

19. Identify the excited gases that produced the following spectra.

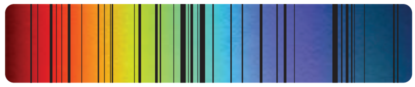
a.



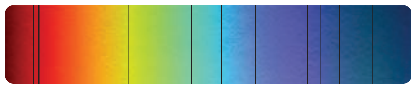
b.

20. Often a spectrum will contain the lines of more than one excited gas. Identify the two gases that produced each of the following spectra.

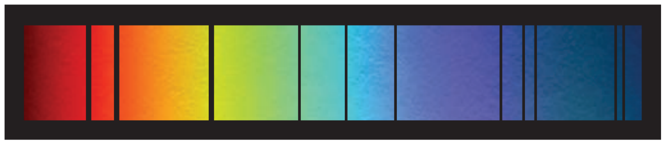
a.



b.



21. The following spectrum was produced by a source that was stationary in relation to the observer.

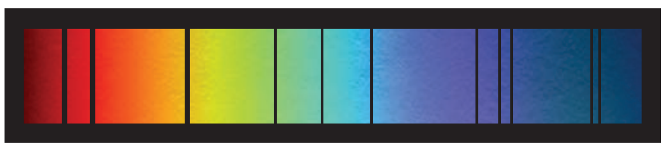


The next spectra were produced by sources that were moving with respect to the observer. In each case, determine whether

- the spectrum is an example of red shift or blue shift
- the source of the spectrum is moving toward the observer or away from the observer

a.

b.



22. Refer to the spectra shown in questions 21.a. and 21.b. Determine which of these two spectra was produced by the faster-moving source. Explain your reasoning.